

QUASI STATIC AND FLEXURAL MECHANICAL PROPERTY EVALUATION OF BASALT/FLAX REINFORCED COMPOSITES

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Abstract. Basalt fiber is one of the best reinforcing materials and satisfies all the needs of a composite material. Flax is predominately used natural fiber which has better mechanical and sudden load shock-absorbing properties. The general-purpose polyester resin in one an excellent binding agent which equally distributes the load along the direction of applications. To understand the mechanical properties of the natural and synthetic fiber of these flax/basalt fiber combinations is essential to reduce the usage of synthetic fibers. In this paper, the maximum tensile strength was found on the combination of pure 10 layers of basalt and it was about 185MPa. The maximum flexural strength absorption was seen in the combination of 10 layers of basalt fiber composite about 190MPa. The maximum impact energy was absorbed by composite D, the alternative layers of basalt and flax fiber composite. SEM analysis shows with matrix cracking, and fiber twist was seen, this is because of the improper mixing of the fiber and matrix shows this type of internal failure, the fiber pulls out and blow holes in between the fiber and matrix also seen in the composites.

Keywords: basalt fiber, flax fiber, polyester resin, quasi-static mechanical behavior, tensile test, impact test

1. Introduction

Flax fiber is a food crop cultivated in cooler regions of the world. It is mainly used in textile industries. They have good mechanical properties and also shock-absorbing properties. Basalt is a dark-colored, fine-grained, igneous rock composed mainly of plagioclase and pyroxene minerals. It most commonly forms as an extrusive rock, such as a lava flow. The cost of the basalt fiber was found to be comparatively cheaper than that of carbon fiber and this basalt/flax combination shows better static and dynamical properties [1]. The combination of hybrid composite is of flax and basalt powder. It comprises of 10 layers of flax fiber and basalt fiber. The mechanical properties of flax fiber and basalt fiber combination possess better results. The fabrication of those composites was made from a compression molding technique which is responsible for achieving some better results. It was found the addition of flax layers increased the amount of energy absorption [2]. The combination of a hybrid combination of carbon and basalt fiber has better tensile strength were found. The materials included were carbon and basalt along with epoxy resin Vacuum bagging process is the process used to fabricate the composite. The testing included are hardness, tensile, and thermal conductivity tests. The carbon/basalt fiber seemed to have better mechanical properties orientation at the angle of 90 degrees than 45 degrees [3]. The combination of hybrid composite is of glass and Kevlar yarns. The effect of homogeneous and hybrid

external patches in weave was noted in the woven glass fibers. The composite fabrication with glass and Kevlar yarns and the matrix material used here is epoxy resin. The better result of the provides the repair applications of the Kevlar mainly as polar fibers [4]. The combination of the basalt and epoxy resin shows better characteristics and mechanical properties, while assorted with the short basalt fiber composites. The better shear and mechanical properties were seen, by increasing the basalt content in the composite improve the strength of the composite [5]. The tensile behavior of the woven basalt fiber composites possesses a high strain rate. Basalt dry fabric was the material used here and the resin was used with the epoxy composites. The testing of quasi-static and dynamic testing results with better results and impact applications [6]. The glass fiber and basalt fiber composite and their mechanical behavior were in comparison. The composite included increasing the percentage of glass fiber content in the composite. These composites showed better and increased tensile and shear strength than other combinations [7]. The combination of hybrid composite is of plain weave fabrics and composite sheet. At different strain rates of flax fiber-reinforced composites, the improved strain rate was noted [8]. The combination of hybrid composite is of flax/basalt fiber. With the topological approach in optimizing mechanical properties flax/basalt fiber hybrid composite. The flexural test, impact results shows that hybridization reduced the brittleness and offered good yield property, the internal damages of the composites studied with SEM [9]. The combination of hybrid composite has good environmental durability in the case of carbon/flax fiber hybrid composites. The tensile test and flexural test was done with hydrothermal treatment changes in surface morphology was studied with SEM analysis. The final result comprises, the addition of flax fiber improved the mechanical properties of the composites [10]. The hybrid combination of flax fiber and basalt fiber results with better bending strength and flexural test, the failure morphology was studied through SEM analysis. The increase in flax fiber as reinforcement in the composite increases the impact bending of the composites [11]. A thorough literature study shows that the combination of basalt and flax fiber possesses better mechanical properties. By nature, the hybridization of basalt and flax fiber offers a good bonding towards quasi-static (tensile and impact) and flexural mechanical studies for various applications.

2. Materials and Methods

The reinforcement material used here was woven flax and basalt fiber and matrix material as general-purpose polyester resin. The additives used were methyl ethyl ketone peroxide (MEKP) is an accelerator and cobalt naphthalate as the catalyst. The flax fiber was purchased from vruksha fibers Guntur and the resin was purchased from vasavi Bala resins, Chennai. Composite prepared by varying the sequence of flax and basalt fiber. And the fabrication was done by compression molding technique with 100kgf/cm^2 pressure at room temperature for 3 hours.

3. Result and Discussion

In this chapter, the hybridization effect of bi-directional basalt/flax fiber and the morphological analysis for tensile, flexural, and impact properties are also discussed with scanning electron microscopy (SEM). The fiber was arranged with different stacking order and their mechanical properties are analyzed for further studies in this chapter.

Table 1. Composite type and specimen code

Specimen code	Flax/Basalt Stacking
A	10L of Flax
B	5L of Flax/ 5L of Basalt
C	2L F/2LB/2L F/2LB/2L F
D	2L B/2L F/2L B/2L F/2L B
E	3L F/2L B/3 L F/2L B
F	4L F/2L B/2L F/2L B
G	3L B/2L F/3L B/2LF
H	4L B/2L F/2L B/2L F
I	10L of Basalt

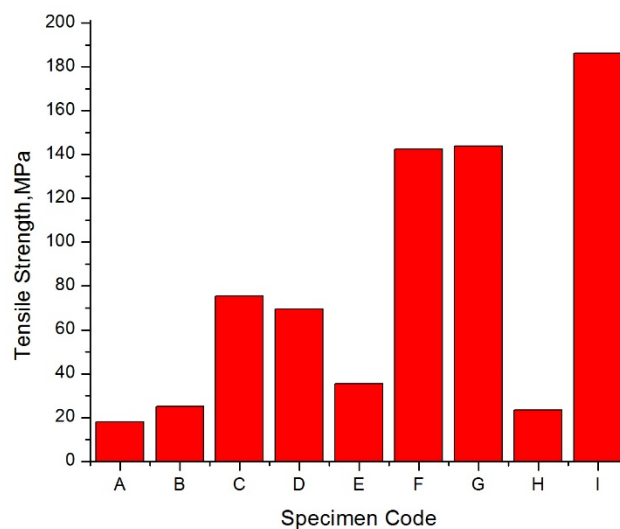


Fig. 1. Tensile strength analysis of flax/basalt fiber composite

Tensile Strength. The tensile strength of the material determines the maximum strength that the material withstand while pulling with some force. The tensile test was carried out with the ASTM D3039 standard and the dimension of the specimen about 200×20×3 mm. The test was executed in the universal testing machine (UTM). This tensile test helps to study the ductile property of the material in various loading conditions. The tensile strength of the material depends on the like preparation of material, fabrication standard, and the temperature adopted for processing. The above table 1 shows the specimen code and different stacking of flax and basalt fiber composite. Figure 1 clearly, defines the tensile strength exhibited by different layers of flax and basalt fibers. The maximum tensile strength acquired by pure 10 layers of basalt fibers (composite I) around 185MPa, by nature the strength absorbing capability for basalt fiber was good while compared to flax fibers. In the hybridization of basalt and flax fiber as alternate sequences, basalt as the first layer, and flax in the last seen in the composite F and G. These composites produce a better performance compared with other combinations of hybrids about 145MPa. Because the linear relationship between the fiber

arrangement and tensile modulus was good, increases the load-bearing capacity of the composite [6]. From the overall comparison, the hybridization of basalt/flax fiber shows better results compared with all other combinations except the pure basalt composite. This results in the combination of flax/basalt produce good tensile strength. However, the pure basalt layer can have performed.

Flexural Strength. The flexural test is also known as the modulus of rupture which denotes the property of the material resists the deformation bending. The flexural test was carried out on the universal testing machine (UTM) with a three-point bending fixture. The test was conducted with the standard of ASTM D790 with a dimension of $125 \times 13 \times 3$ mm. This flexural strength of the composite represents the highest stress experienced within the reinforcement fiber to the matrix material. There is a better flexural energy capability was noted for basalt and flax fiber composite [7]. Figure 2 shows the flexural strength analysis of flax/basalt fiber composite. The maximum flexural strength absorption was seen in the 10 layers of basalt fiber composite about 190MPa, this is because the failure of the composite happens as a straight-line crack. This type of crack pattern does not experience a major failure in the composite, especially for basalt fiber composites [8]. The combination hybridization effect of basalt/flax alternate layers possess some better flexural results in the layering effect of the composite. In composite F, the alternate layers of basalt and flax fiber show some noted results about 140MPa. The flexural strength of the composites depends on the stress concentration and load absorbing capability of the composite. And the bonding of fibers with the matrix is also considered to be an important content while study about the flexural strength of the composite. As synthetic fiber basalt shows a better performance in this area also, reduce the usage of basalt fiber in the stack will be eco-friendly. The alternative sequence of basalt and flax fiber shows good strength compared with other combinations.

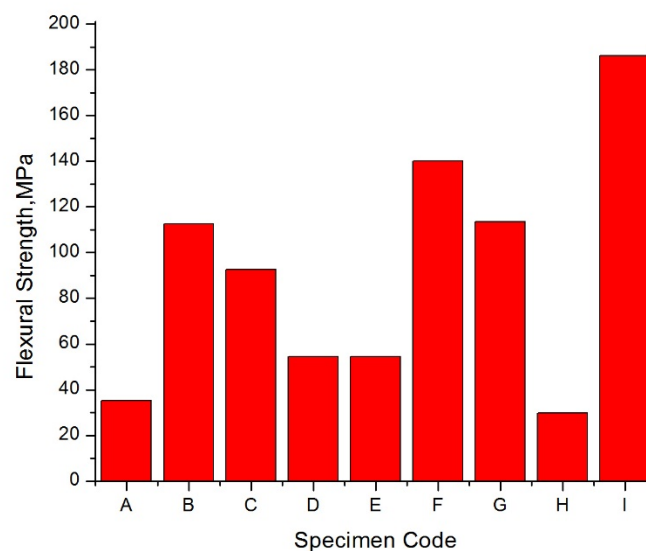


Fig. 2. Flexural strength analysis of flax/basalt fiber composite

Impact Strength. Impact strength determines the sudden load capability of the material and its related properties. In polymer composites, the impact strength was considered to be an important property of the material towards the fracture. The charpy impact test was examined with ASTM D256 with the specimen dimension of $65 \times 13 \times 3$ mm. The maximum impact energy was absorbed by composite D, the alternative layers of basalt, and flax fiber composite. The energy absorbed around 25J, this shows the hybrid application of basalt and

flax for various mechanical applications. The impact performance of basalt hybrid composite depends on the elastic modulus of the supportive reinforcement. However, the combination of flax reinforcement with basalt always has a high elastic modulus [9] than other fibers as reinforcement. The other combinations as 10 layers of pure basalt (composite A) and flax (composite I) type of composite do not show a better impact response compared to these hybrids. From the overall observations, the alternative layers of basalt and flax fiber composite produce a good impact strength towards the application of sudden load.

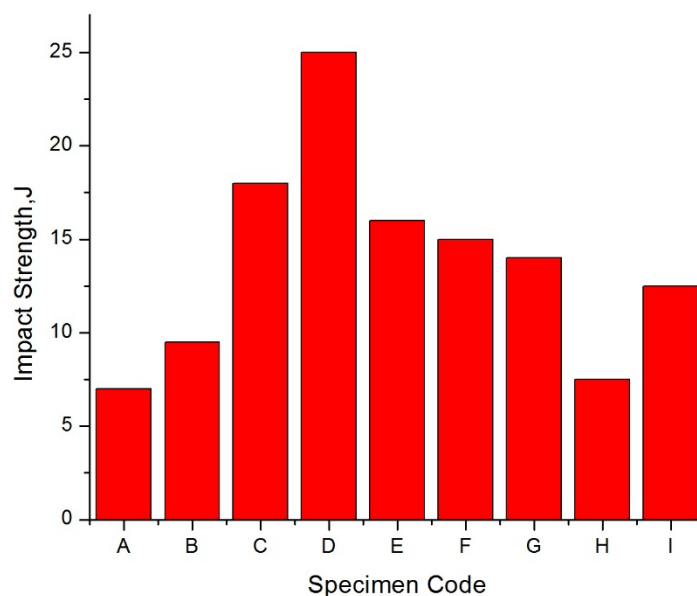


Fig. 3. Flexural strength analysis of flax/basalt fiber composite

Morphological Analysis. Morphological analysis is one of the general problem solving and provides a better solution for any of the approaches. In polymer composite, the morphological study helped to examined through microscopy for mechanical failures. Scanning Electron Microscope (SEM) is one type of technique to study the failure and factors responsible for the failure were studied with the electron microscope. The internal structure specimen was affected by cracks and holes, due to the application of mechanical loads. Figure 4 shows the SEM analysis of mechanical testing as tensile, impact, and flexural test of alternate layers of flax and basalt fiber composite, which shows better results compared to other combinations. Figure 4a shows the failure analysis of the tensile specimen, in that the matrix crack was noticed this is due to not proper bonding between the reinforcement and matrix responsible for this type of failure [10]. Figure 4b shows the SEM analysis of the flexural specimens, in that the fiber twist was seen this is because of the improper mixing of the fiber and matrix shows this type of internal failure observation. In the impact specimen fiber pull out and blow holes in between the fiber and matrix were noted [11]. This is the type of response that can observe only improper curing time of fabrication and blowholes for the bending of fibers which initiate the crack without the responses of the matrix in the time of application of load [12], shown in Fig. 4c as impact responses.

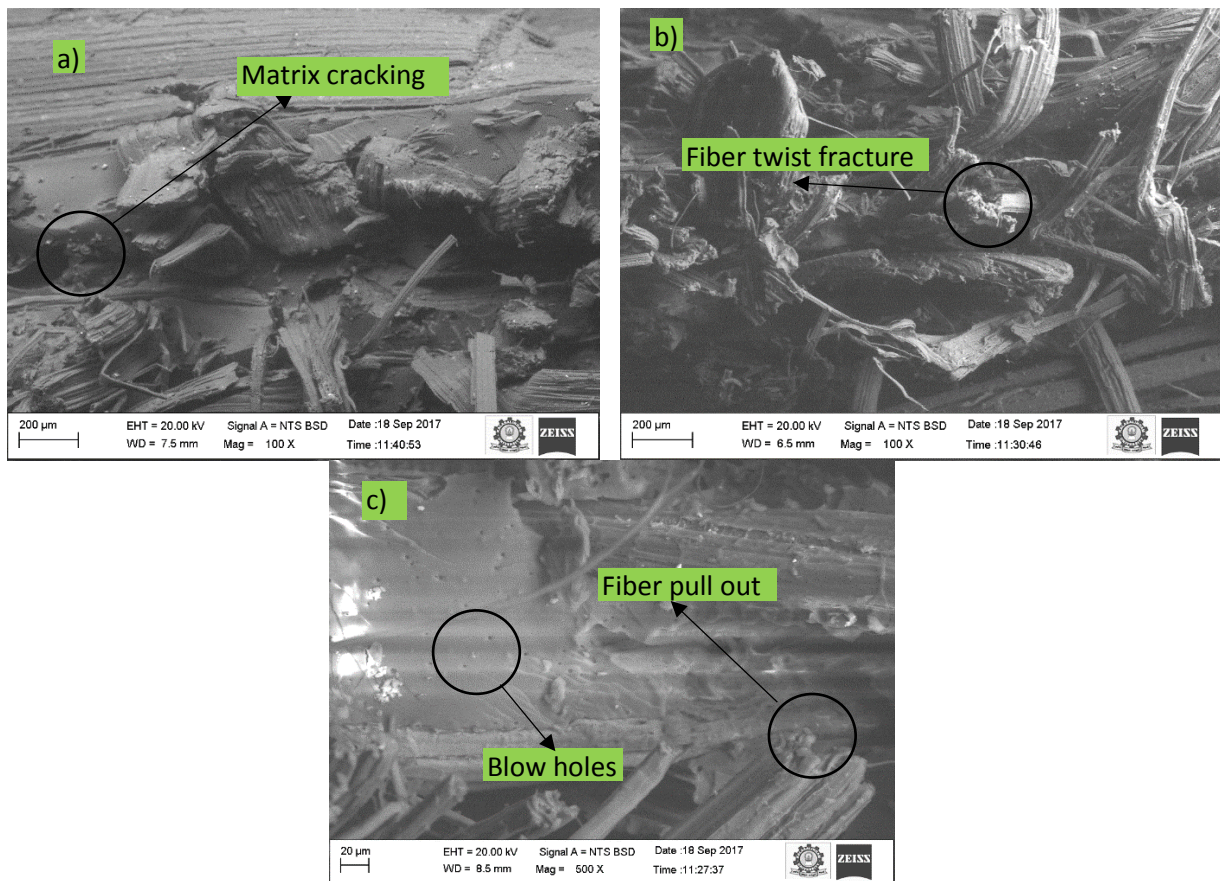


Fig. 4. SEM morphological analysis of flax/basalt fiber composite

4. Conclusion

1. The maximum tensile strength acquired by pure 10 layers of basalt fibers (composite I) around 185MPa, by nature the strength absorbing capability for basalt fiber was good while compared to flax fibers. In the hybridization of basalt and flax fiber as alternate sequences, basalt as the first layer, and flax in the last seen in the composite F and G.
2. The maximum flexural strength absorption was seen in the 10 layers of basalt fiber composite about 190MPa, this is because the failure of the composite happens as a straight-line crack. This type of crack pattern does not experience a major failure in the composite, especially for basalt fiber composites.
3. The alternate layers of basalt and flax fiber show some noted results about 140MPa. The flexural strength of the composites depends on the stress concentration and load absorbing capability of the composite.
4. The energy absorbed around 25J, this shows the hybrid application of basalt and flax for various mechanical applications. The impact performance of basalt hybrid composite depends on the elastic modulus of the supportive reinforcement.
5. The SEM analysis of the tensile specimen, in that the matrix crack was noticed this is due to not proper bonding between the reinforcement and matrix responsible for these types of failure. The fiber twist was seen this is because the improper mixing of the fiber and matrix shows this type of internal failure observation. In the impact specimen fiber pull out and blow holes in between the fiber and matrix were noted.
6. From the results obtained theoretically and experimentally, the combination of basalt and flax fiber composite shows better impact strength than other mechanical properties.

This hybrid combination has the application in automobile and aircraft components with the replacement of metals.

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References

- [1] Prasath KA, Amuthakkannan P, Arumugaprabu V, Manikandan V. Low velocity impact and compression after impact damage responses on flax/basalt fiber hybrid composites. *Materials Research Express*. 2019;6(11): 115308.
- [2] Attia Mohamed A, Marwa Abd El-baky A, Mostafa Abdelhaleem M, Mohamed Hassan A. Hybrid composite laminates reinforced with flax-basalt-glass woven fabrics for lightweight load bearing structures. *Journal of Industrial Textiles*. 2020. Available from: <https://doi.org/10.1177/1528083720960743>.
- [3] Atmika IK, Subagia ID, Surata IW, Sutantra IN. Hardness and wear rate of basalt/alumina/shellfish powder reinforced phenolic resin matrix hybrid composite brake lining pads. In *IOP Conference Series: Materials Science and Engineering*. 2019;23(4): 13-25.
- [4] Abd El-baky M, Mostafa Abdelhaleem M, Hassan A. Mechanical characterization of hybrid composites based on flax, basalt and glass fibers. *Journal of Composite Materials*. 2020. Available from: <https://doi.org/10.1177/0021998320928509>.
- [5] Doddi PR, Chanamala R, Dora SP. Dynamic mechanical properties of epoxy based PALF/basalt hybrid composite laminates. *Materials Research Express*. 2019;6(10): 105343.
- [6] Elmahdy A, Verleysen P. Mechanical behavior of basalt and glass textile composites at high strain rates: A comparison. *Polymer Testing*. 2020;81: 106224.
- [7] Fiore V, Calabrese L. Effect of stacking sequence and sodium bicarbonate treatment on quasi-static and dynamic mechanical properties of flax/jute epoxy-based composites. *Materials*. 2019;12(9): 1363.
- [8] Prasath KA, Amuthakkannan P, Arumugaprabu V, Manikandan V. Low velocity impact and compression after impact damage responses on flax/basalt fiber hybrid composites. *Materials Research Express*. 2019;6(11): 115308.
- [9] Sarasini F, Tirillò J, Ferrante L, Sergi C, Sbardella F, Russo P, Simeoli G, Mellier D, Calzolari A. Effect of temperature and fiber type on impact behavior of thermoplastic fiber metal laminates. *Composite Structures*. 2019;223: 110961.
- [10] Niu D, Su L, Luo Y, Huang D, Luo D. Experimental study on mechanical properties and durability of basalt fiber reinforced coral aggregate concrete. *Construction and Building Materials*. 2020;237: 117628.
- [11] Frydrych M, Hýsek S, Fridrichova L, Le Van S, Herclík M, Pechociakova M, Le Chi H, Louda P. Impact of Flax and Basalt Fibre Reinforcement on Selected Properties of Geopolymer Composites. *Sustainability*. 2020;12(1): 118.
- [12] Sarasini F, Tirillò J, Ferrante L, Sergi C, Russo P, Simeoli G, Cimino F, Ricciardi MR, Antonucci V. Quasi-Static and Low-Velocity Impact Behavior of Intraply Hybrid Flax/Basalt Composites. *Fibers*. 2019;7(3): 26.